RESEARCH STUDY TO DETERMINE CRITICAL OPTICAL/MECHANICAL PROPERTIES OF MATERIALS CONSIDERED FOR SELECTION AS SUBSTRATES FOR THE PRIMARY MIRROR ON A LARGE TELESCOPE

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SUMMARY

An investigation was conducted to evaluate the stability of a specific low expansion glass-ceramic material relative to its use as a large, lightweight mirror substrate for diffraction-limited spaceborne optical applications.

These evaluations were made on a segment (0.44 meter diameter by 0.31 meter thick) of a 2 to 3 meter diameter mirror blank. The material used was CerVit, type C-101, made by Owens-Illinois. The dimensional stability of this mirror was measured interferometrically before and after lightweighting, as a function of rough machining, etching, thermal environment, and support configuration.

Test data on the solid mirror blank showed no measurable change in figure (i.e., less than 1/20 of a wavelength (λ) of 0.63μm), of the optical surface when it was measured at 293.15°K, 273°K, and 216.15°K (20°C, 0°C, and -57°C). No change in surface figure caused by self-weight was observed among three mounting arrangements (3 point support - 2.1r (120°) apart located, respectively, at 0.25, 0.66, and 0.91 of the radius). No measurable change in the absolute radius of curvature was observed after one thermal cycle to 215°K (-58°C).

Test data on the mirror after lightweighting showed small surface irregularities (λ/10 in magnitude) occurring in a zone representing about 10% of the mirror area, and located slightly off-center. During the etching program these small irregularities smoothed out leaving a low area approximately λ/5 deep over the same area. No measurable figure change was observed to have occurred through twenty (20) thermal cycles from 293.15°K to 216.15°K (20°C to -57°C). Nor was any change detected among the three different mounting support locations.

A special computer analysis program was used to plot the coefficients corresponding to aberrations with sixfold symmetry (caused by the mirror's self-weight deflection on a three point support). The objective was to enhance the test sensitivity. Results indicate that any such effects due to self-weight deflection are of the order of 0.015λ rms. Table 1 summarizes the rms and peak-to-peak figure changes associated with each processing operation.

The excellent stabilities shown after machining, etching, and during and after thermal changes indicate that premium grade CerVit (type C-101) is a very attractive candidate for large telescope mirrors.

TABLE I. SUMMARY OF SURFACE FIGURE CHANGES

Solid Mirror

Condition	Optical Figure (Fractional Wavelength*) p.p.	r.m.s.	Measurement Aperture
Initial (0.66R, 20°C)	0.2991	0.0390	95%
Initial (0.66R, 20°C)	0.3981	0.0631	100%
0°C	0.4206	0.0611	100%
-57°C	0.2837	0.0401	100%
0.25R	0.3803	0.0585	100%
0.66R	0.3981	0.0631	100%
0.91R	0.4702	0.0625	100%

Lightweighted Mirror

Condition	Figure p.p.	r.m.s.	Measurement Aperture
After Lightweighting	0.2970	0.0576	95%
After Etching	0.6782	0.1177	95%
20°C	0.5532	0.1108	95%
0°C	0.3271	0.0660	95%
-57°C	0.4381	0.0789	95%
0.66R	0.7386	0.0957	95%
0.25R	0.7100	0.1675	95%
0.91R	0.7042	0.1023	95%
Before Thermal Cycling	0.4895	0.0986	95%
After 20 Thermal Cycles to -57°C	0.4644	0.0918	95%

*$\lambda = 0.6328 \mu m$.

1.0 INTRODUCTION

1.1 PROGRAM OBJECTIVE

The objective of this program is to evaluate and optimize current process technology in the fabrication of large, lightweight mirror structures for the Large Space Telescope. Specifically, the integrity and stability of a solid and lightweighted mirror blank were determined as a function of temperature, mounting configuration, and the important mechanical and optical processing steps typical of those to be experienced in fabrication of 2 to 3 meter diameter primary mirrors. In this study, a small segment (0.44m diameter by 0.31m thick) of a 2 meter primary, made of the low expansion glass-ceramic, CerVit type C-101, was evaluated.

1.2 PROGRAM PLAN SUMMARY

This program has been structured to be accomplished in two distinct phases. First, the mirror as a solid was evaluated. Secondly, after lightweighting, the same mirror was retested and compared to its performance under the first phase. Details of these two phases are given below:

1.2.1 Phase I - Evaluation of the Solid CerVit Blank

This activity was conducted to determine the optical/mechanical properties of a solid optical mirror as a function of thermal environment and mechanical support configuration. The following activities were performed:

(a) The NASA/GSFC Technical Officer supplied a mirror blank, nominally of 43.8 diameter by 30.5 cm thick, to Perkin-Elmer.

(b) The blank was inspected by ultrasonic mapping techniques.

(c) The blank was ground and optically polished to a concave spherical shape. This surface was made to a radius of curvature of 236.6 ±0.2cm with a figure accuracy of 0.250λ* as specified.

*at a wavelength λ of 0.6328μm.

(d) Interferograms mapping the entire mirror surface under test were taken at the radius of curvature of the mirror. Peak-to-valley sensitivity of the measurements was 0.1 wavelength as specified.

(e) The absolute radius of curvature of the mirror was measured.

(f) The thermal figure stability of the mirror blank was then measured in a thermal vacuum chamber. Interferograms, taken at temperatures of 293°K, 273°K and 216°K (+20°, 0°, and -57°C), were reduced by numerical methods to yield peak-to-valley and rms deviations from the best fit spherical surface.

(g) Deflection characteristics of the mirror mounted on three point supports located 2.1r (120 degrees) apart on support circles of 0.25, 0.66, and 0.91 of the blank radius were determined.

(h) Following thermal testing and deflection measurements, the mirror blank was to be returned to the GSFC Technical Officer for lightweighting at Owens-Illinois.

1.2.2 <u>Phase II - Evaluation of the Lightweighted CerVit Mirror Blank</u>

This phase was conducted to determine changes, if any, in the optical/mechanical properties of the mirror blank caused by lightweighting. To perform this evaluation the following activities were performed:

(a) Upon receipt of the lightweighted mirror blank from the GSFC Technical Officer, Perkin-Elmer interferometrically recorded the surface optical figure, and measured the absolute radius of curvature of the mirror.

(b) The blank was then inspected by ultrasonic mapping techniques as done previously in Phase I.

(c) All internal surfaces of the lightweighting cavities of the mirror were then etched to a depth of 0.127 cm (0.050 inch). Periodically during the etching process, the optical figure was measured interferometrically to record any changes that occurred.

(d) Following the etching process, the blank was again inspected by ultrasonic mapping techniques.

(e) Thermal figure stability tests were conducted as in Phase I.

(f) The thermal cycling stability of the mirror was determined from comparison of interferograms taken before and after one (1), five (5), and twenty (20) thermal cycles between 293°K and 216°K (20° and -57°C).

(g) Deflection characteristics of the lightweighted mirror were determined by interferometric analysis, under similar conditions as described in Phase I.

(h) Following measurement of the absolute radius of curvature of the mirror, the mirror shall be returned to the GSFC Technical Officer.

2.0 EVALUATION OF THE SOLID CERVIT MIRROR BLANK

2.1 ULTRASONIC TESTING

Ultrasonic mapping tests were conducted on the test piece t evaluate the structural integrity of the CerVit mirror. A high freq ncy (10 MHz) pulse-echo "C" scan recording technique was employed. Essentially, the data output is in the form of a map (x, y surface) in which density (z-information) is printed according to ten shades of gray, depending on the magnitude of the reflected "echo" pulse. Both pulse-echo and transmission ultrasonic scan techniques were used for evaluation of the solid mirror blank.

2.2 ABSOLUTE RADIUS OF CURVATURE MEASUREMENTS

The absolute radius of curvature was measured before and after all thermal and deflection tests, and was measured to an accuracy of 0.25mm.

The measurements recorded were:

Specification Requirement	Actual Measurement	
	Before	After
2366 ± 2mm	2365.8mm ± 0.25mm	2365.4mm ± 0.25mm

In conclusion, no detectable change in radius of curvature was noted following thermal and deflection tests of the solid mirror blank.

2.3 THERMAL MEASUREMENTS

The mirror was supported radially at 3 points, located 2.1r (120 degrees) apart at the 0.66 radial position, and both the mirror and the support were placed in the low temperature vacuum test chamber. The temperature of the test piece was monitored by thermocouples that were attached to the central front and rear surfaces and to various edge locations. The temperature of the test piece was allowed to stabilize for a period of 6 hours

prior to recording any measurements. Interferograms were taken at 293°K, 273°K, and 216°K (20°, 0°, and -57°C). The interferograms were recorded from the mirror's center of curvature and the full clear aperture of the mirror was recorded.

The interferograms were recorded on photographic film. Data reduction was accomplished by automatically scanning the film negative with a microdensitometer, and numerically reducing this data by an XDS-930 computer.

To evaluate the test results the difference measurements between two interferograms were determined by the computer. The interferograms at 293°K and 273°K (20°C and 0°C) were compared, and the interferograms at 273°K and 216°K (20°C and -57°C) were compared. Contour maps shown in Figures 1 and 2 show the difference levels across the mirror surface. The test instrumentation sensitivity was calculated to be approximately $\lambda/20$.

This was well within the specified $\lambda/10$ sensitivity requirements for this program. The peak-to-peak variation in the contour showed no net change greater than $\lambda/20$. This demonstrated that the solid CerVit blank has good uniformity of expansion coefficient and, hence, excellent thermal figure stability.

2.4 SELF-WEIGHT DEFLECTION MEASUREMENTS

The self-weight deflection of the solid CerVit mirror was measured as a function of support position. For the tests, the mirror was mounted on three supports spaced 2.1r (120 degrees) apart. The measurements were taken with the supports at 0.25, 0.66, and 0.91 of the radius of the blank. The 0.91 radial factor was as close to the edge as safety would allow.

At each position, a surface interferogram was taken to record any change in surface figure. All the interferograms were recorded at a room ambient temperature of 293°K (20°C). The test results show that there was no significant change in surface figure greater than $\lambda/20$. Figure 3 compares

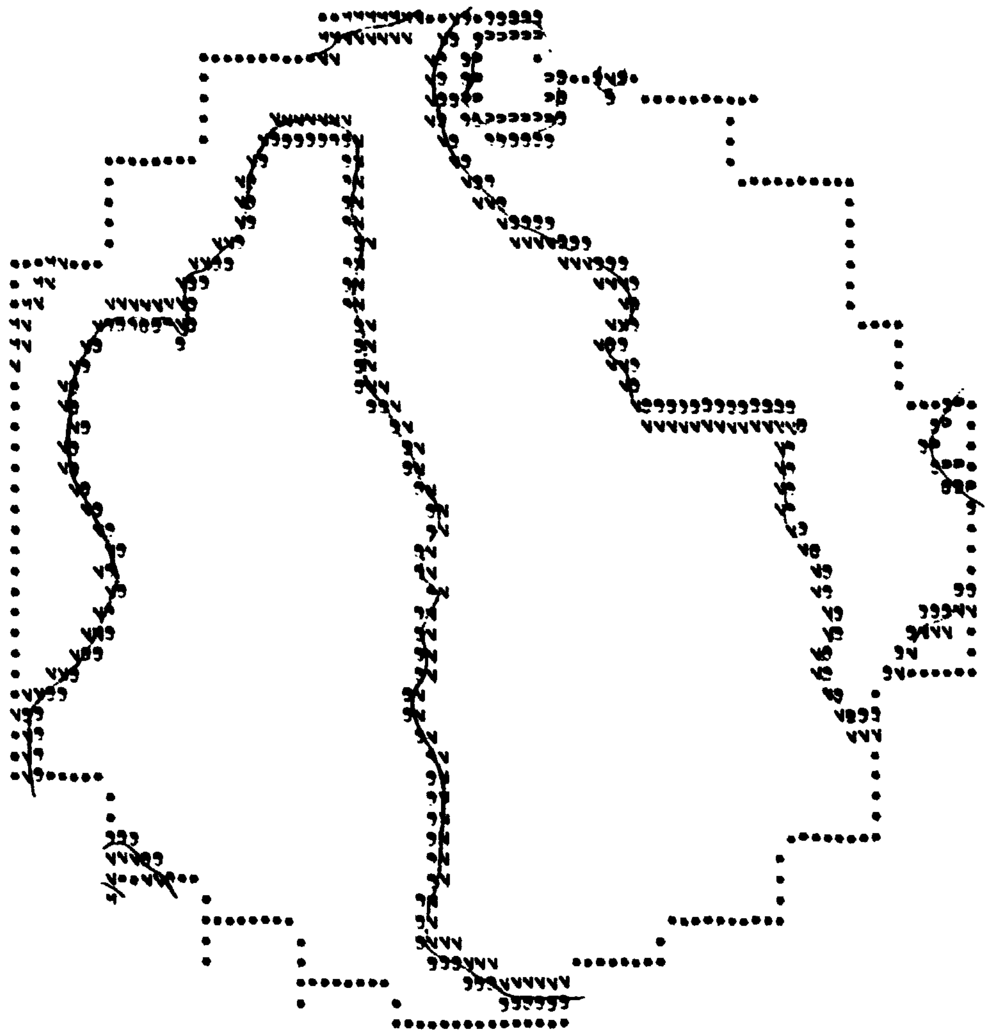
CONTOUR INTERVAL = 0.050λ

KL = -0.150
LM = -0.100
MN = -0.050
NO = ZERO
OP = 0.050
PQ = 0.100
QR = 0.150

NET CHANGE

p.p. = 0.1739λ
r.m.s. = 0.0192λ

Figure 1. Solid Blank - Difference Between 20°C and 0°C

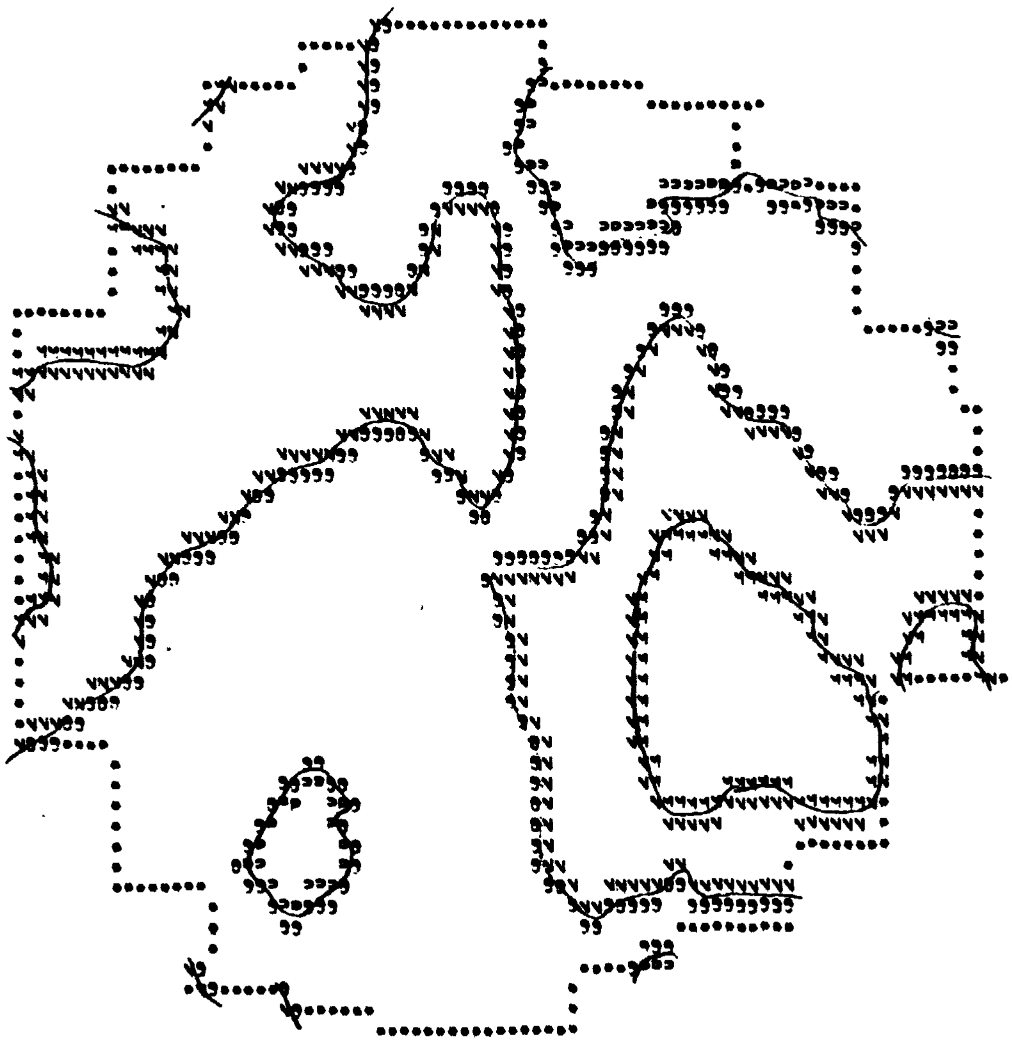


CONTOUR INTERVAL = 0.050λ

KL = -0.150
LM = -0.100
MN = -0.050
NO = ZERO
OP = 0.050
PQ = 0.100
QR = 0.150

NET CHANGE
p.p. = 0.1892λ
r.m.s. = 0.0256

Figure 2. Solid Blank - Difference Between 20°C and -57°C



CONTOUR INTERVAL = 0.050λ

KL = -0.150
LM = -0.100
MN = -0.050
NO = ZERO
OP = 0.050
PQ = 0.100
QR = 0.150

NET CHANGE

p.p. = 0.1691λ
r.m.s. = 0.0343λ

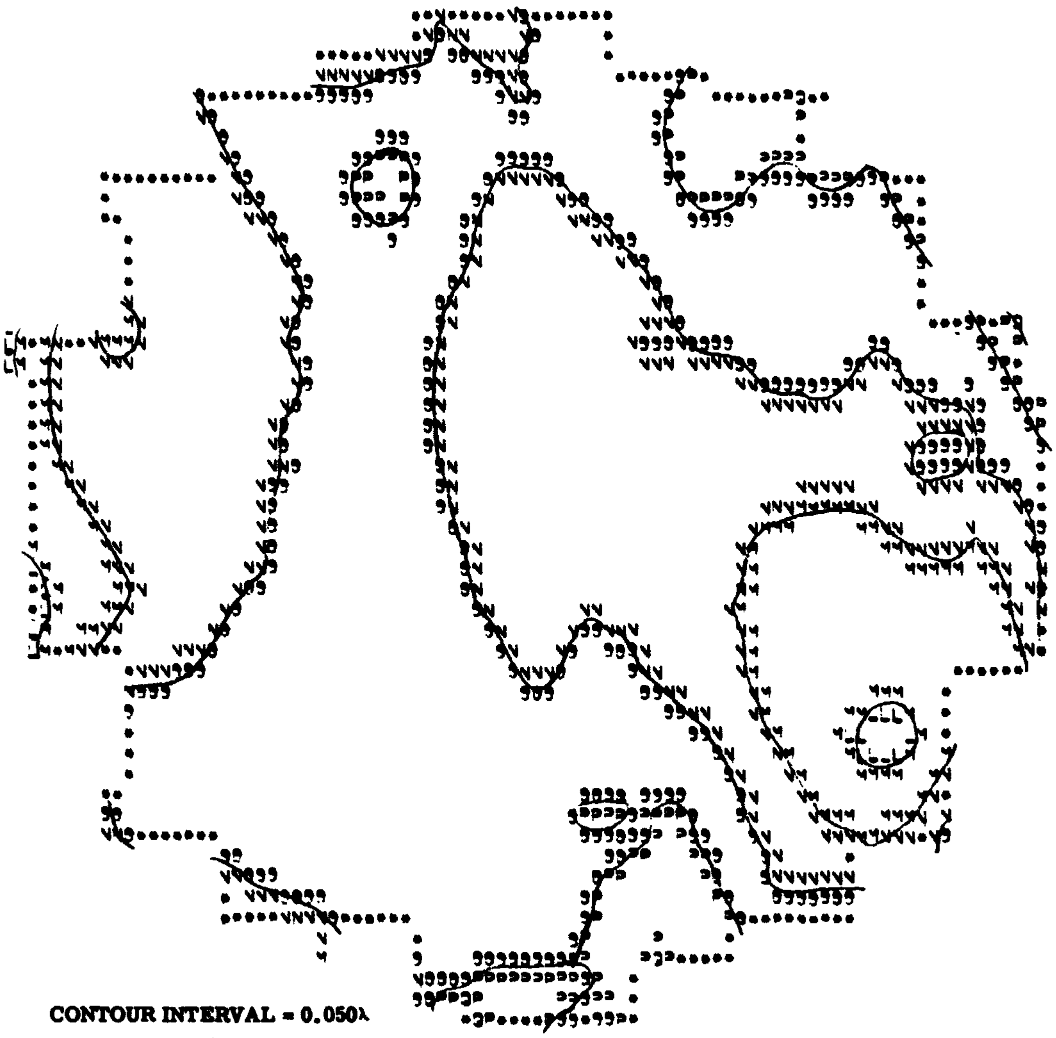
Figure 3. Solid Blank - Difference Between 0.66R and 0.91R Support

the measurements taken at 0.66 and at 0.91 of the radius. Figure 4 compares the interferograms taken at 0.66 and 0.25.

As expected, no measurable deflections were observed because of the thickness of this blank. This data was obtained for reference purposes, and will be compared (in Phase II) to deflection characteristics of the lightweighted blank.

2.5 CONCLUSIONS

The test results of Phase I show the solid CerVit blank has good uniformity of expansion coefficient and hence excellent thermal figure stability. As might be expected with a test piece having such a low aspect ratio, the optical figure remained unchanged for varying radial support conditions.



CONTOUR INTERVAL = 0.050λ

KL = -0.150
LM = -0.100
MN = -0.050
NO = ZERO
OP = 0.050
PQ = 0.100
QR = 0.150

NET CHANGE

p.p. = 0.2520λ
r.m.s. = 0.0393λ

Figure 4. Solid Blank Difference Between 0.66R and 0.25R Support

3.0 EVALUATION OF THE CERVIT MIRROR AFTER LIGHTWEIGHTING

After completion of Phase I, the mirror was lightweighted at Owens-Illinois. The weight of the CerVit mirror was reduced from 160 kg to 54 kg by removing seven hexagonally shaped cores. (Appendix A contains the Owens-Illinois lightweighting report.) The mirror was then returned to Perkin-Elmer for the performance of Phase II measurements as outlined in Section 1.2. The lightweight configuration is shown in Figure 5.

3.1 ULTRASONIC AND RADIUS OF CURVATURE MEASUREMENTS

After receipt of the mirror from Owens-Illinois, the mirror was ultrasonically scanned. No structural defects were found. Next, the absolute radius of curvature was measured. No change was found to have occurred.

3.2 POST-MACHINING MEASUREMENTS

Interferograms recording the optical figure of the lightweighted mirror were taken and compared to a reference interferogram made of the surface figure prior to machining. These are shown in Figure 6. Figure 7 is a computer generated contour map showing the net change in the mirror as a result of the lightweighting, which was obtained by subtracting Figure 6b from 6a. The interferograms show very localized and small irregularities (approximately $\lambda/10$ in magnitude) in a broad area located off-center and occupying approximately 10% of the mirror's surface area.

3.3 OPTICAL SURFACE FIGURE AFTER ETCHING

The lightweight CerVit blank as received from Owens-Illinois had its cavity surfaces intentionally left in their as-machined condition, i.e., no chemical etching for stress relief purposes had been done on the machined surfaces. Web thicknesses were nominally 0.89cm (0.350 inch) thick. All interior machined surfaces of the blank were then etched to remove any stressed material introduced by the machining process and to arrest propagation of surface cracks if present. A total of 0.127cm (0.050 inch) was uniformly removed from all interior surfaces in seven increments resulting in a final web thickness of 0.635cm (0.250 inch).

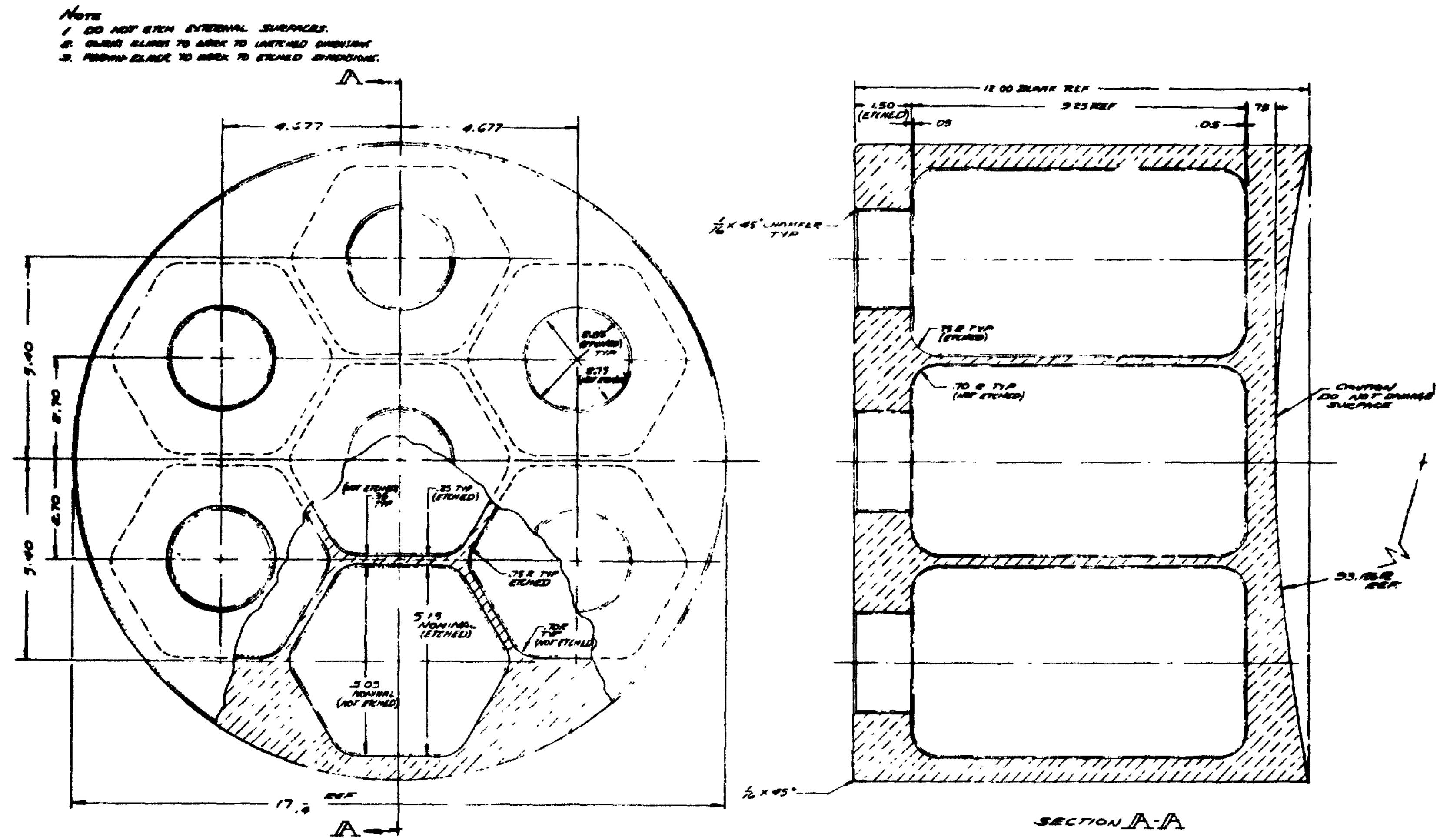
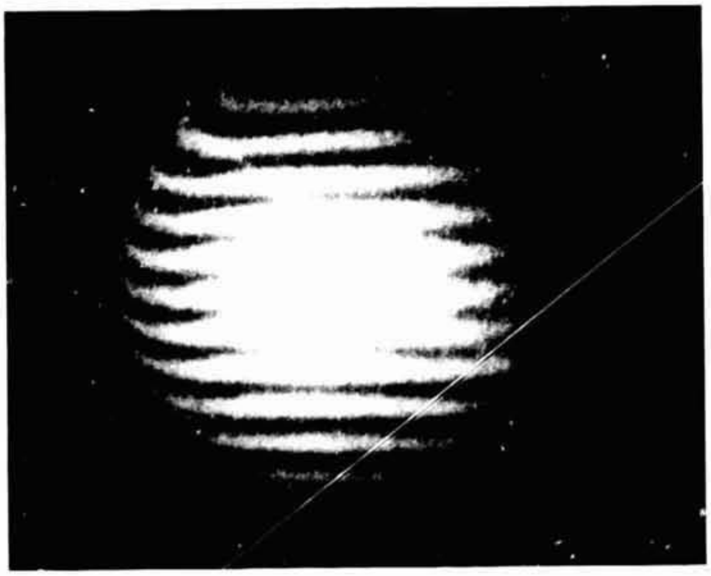
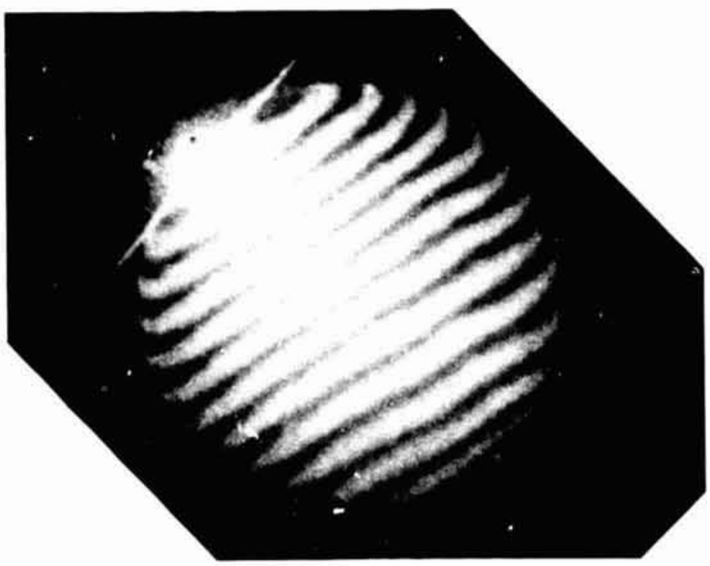


Figure 5. Plan of Lightweight Mirror

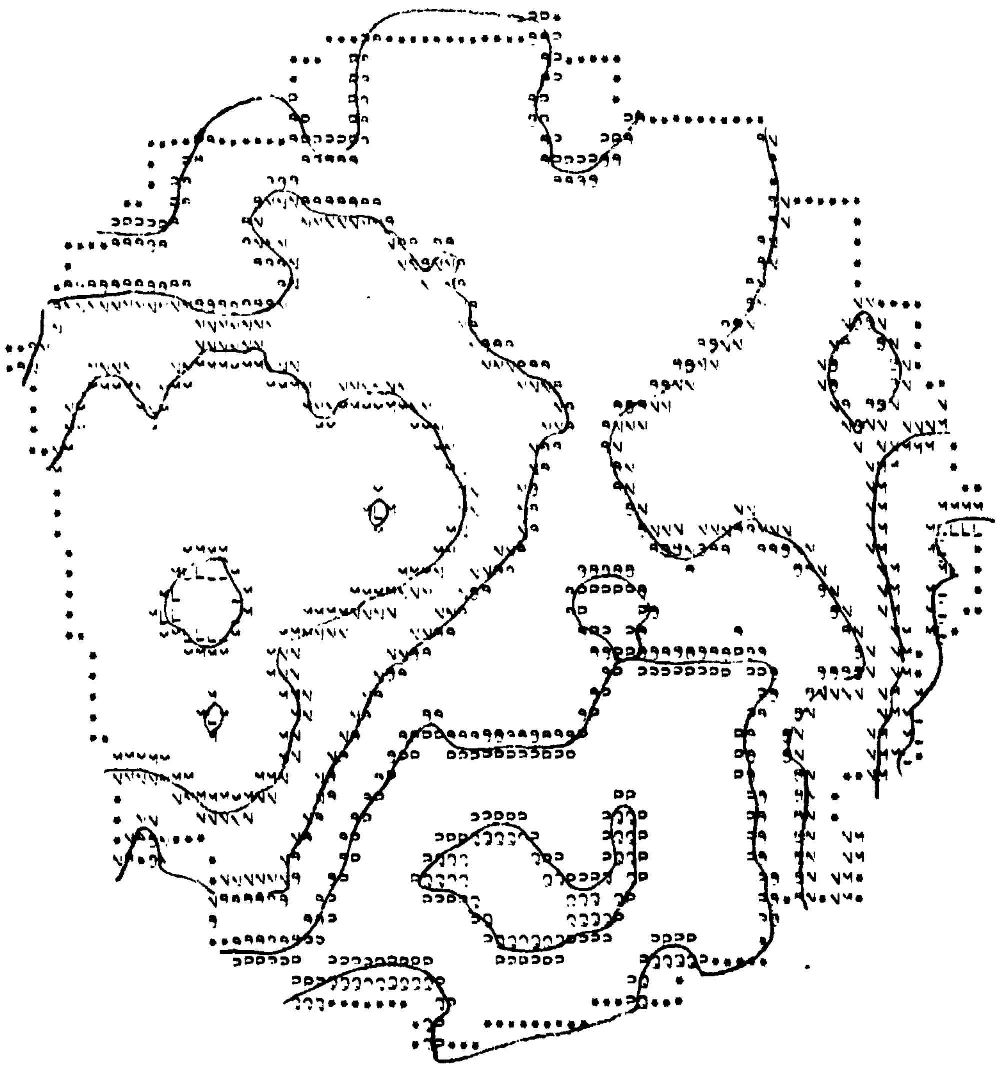


Before



After

Figure 6. Figure Change Due to Lightweighting



CONTOUR INTERVAL = 0.050λ

KL = -0.150
LM = -0.100
MN = -0.050
NO = ZERO
OP = 0.050
PQ = 0.100
QR = 0.150

NET CHANGE

p.p. = 0.2732λ
r.m.s. = 0.0567λ

Figure 7. Net Change Due to Lightweighting

Interferograms were taken following each increment. Surface figure changes were observed immediately and continued to grow until 0.014 cm (0.006 inch) of CerVit, per machined surface, was removed. No further change occurred during removal of the remaining 0.112 cm (0.044 inch) from each surface. These changes are plotted in Figure 8.

Figure 9, which compares interferograms of the mirror after machining and after etching, shows the figure change to be a zone approximately $\lambda/5$ in depth which is nearly centered with respect to the central cavity. Figure 10 is a contour map of the net change in the workpiece due to etching.

3.4 THERMAL MEASUREMENTS

3.4.1 Thermal Stability

The mirror was supported radially at three points located 2.1r (120 degrees) apart at the 0.66 radial position. The mirror and its mounting structure were placed in the low temperature vertical vacuum test chamber. The temperature of the mirror was monitored with thermocouples attached to the faceplate, inside the central cavity, the backing plate, and to the side of the mirror. Mirror temperature was allowed to stabilize for a period of three hours at 273°K (0°C) and for six hours at 216°K (-57°C) before measurement. Interferograms were recorded at 293.15°K, 273.15°K and 216.15°K (20°, 0°, and -57°C) using an equal-path interferometer. Figures 11 and 12 are contour maps that give the net change in surface figure at 273°K and 216.15°K (0° and -57°C) relative to the figure at 293.15°K (20°C). These maps were made by subtracting the 273°K and 216.15°K (0°C and -57°C) interferograms from the 293.15°K (20°C) interferograms. To the limit of sensitivity ($\pm\lambda/20$), no change in optical figure was observed at either temperature.

3.4.2 Thermal Cycle Tests

After completion of deflection testing (which shall be described in Section 3.5), the mirror was placed in a MIL-qualified environmental test chamber and automatically cycled twenty times between 293°K and 216°K (20°C

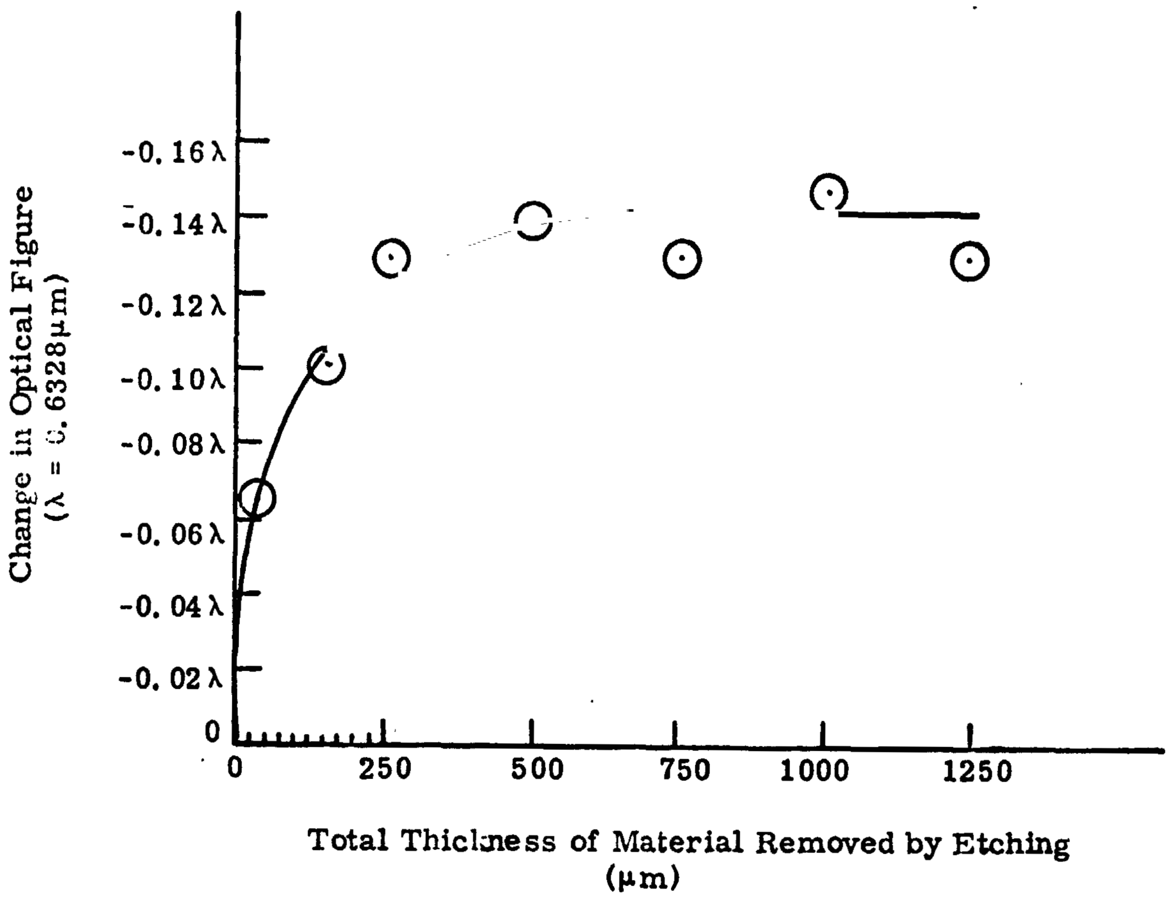
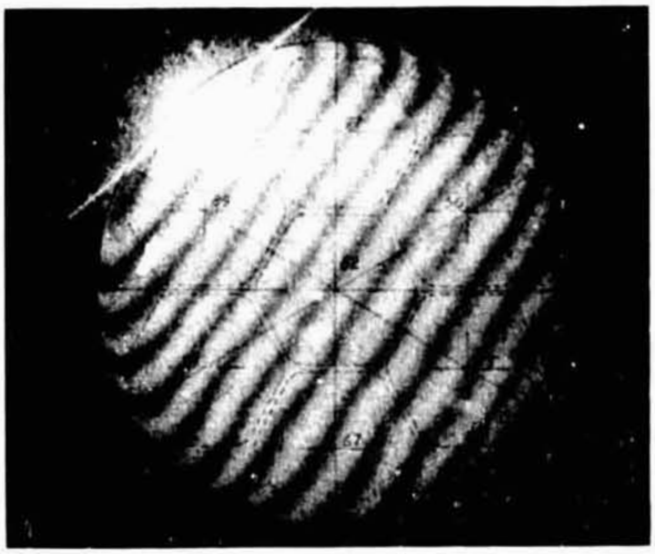
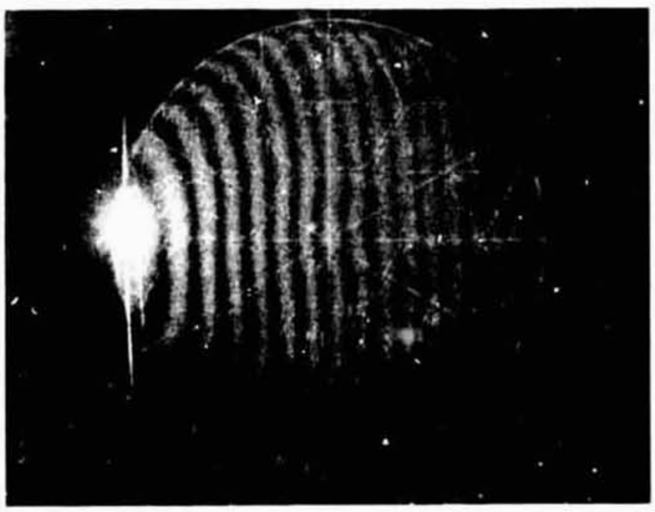


Figure 8. Change in Optical Figure Across Cavity #82 as a Function of Etch Depth

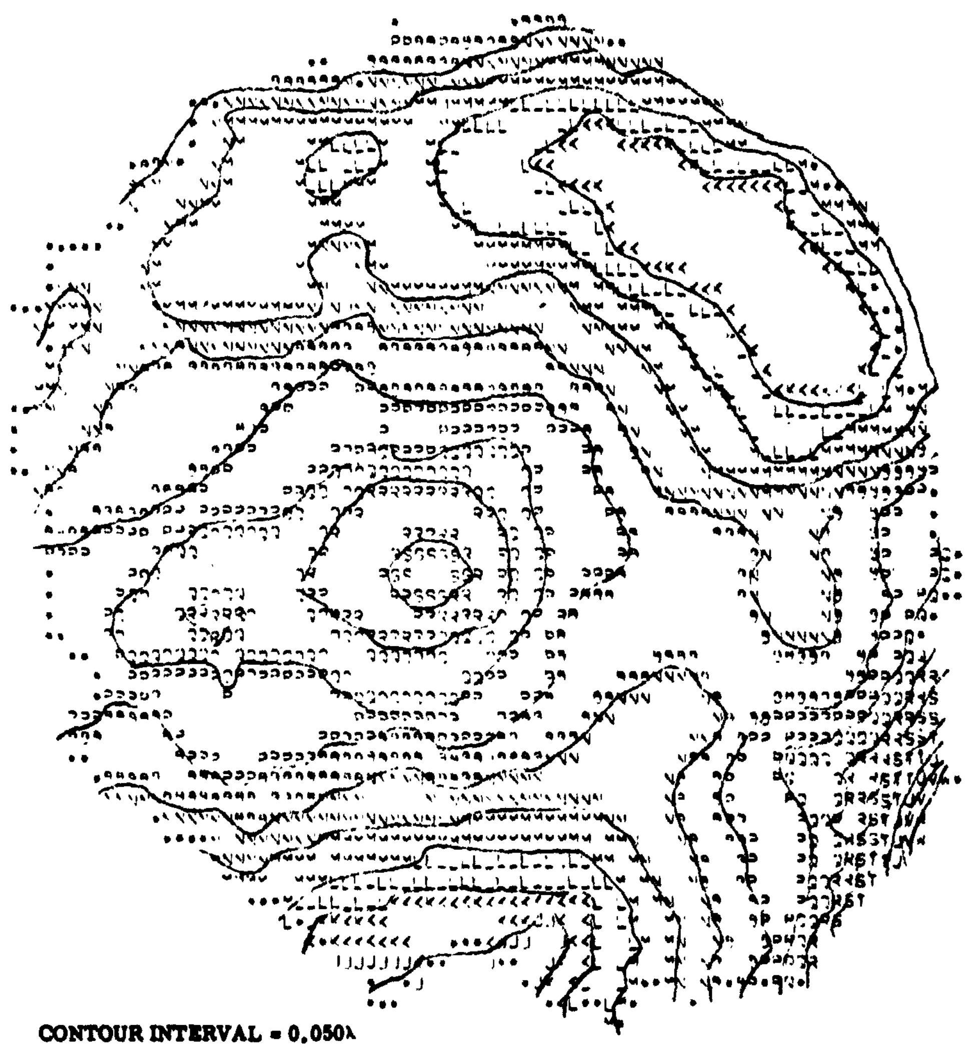


(a) Before



(b) After

Figure 9. Figure Change Due to Etching



CONTOUR INTERVAL = 0.050λ

KL = 0.150
LM = 0.100
MN = 0.050
NO = ZERO
OP = -0.050
PQ = -0.100
QR = -0.150

NET CHANGE

p.p. = 0.3997λ
r.m.s. = 0.0829λ

Figure 10. Net Change Due to Etching

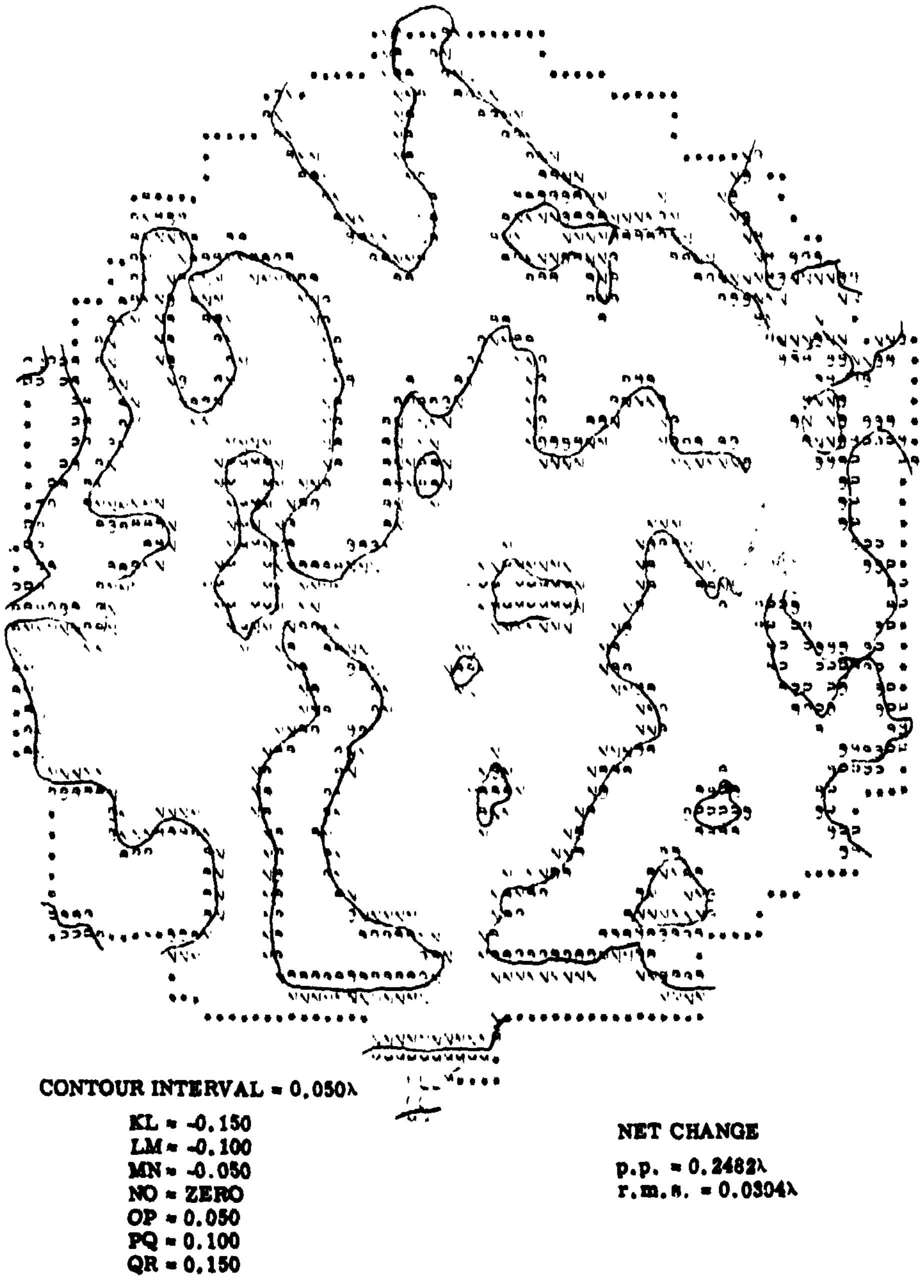
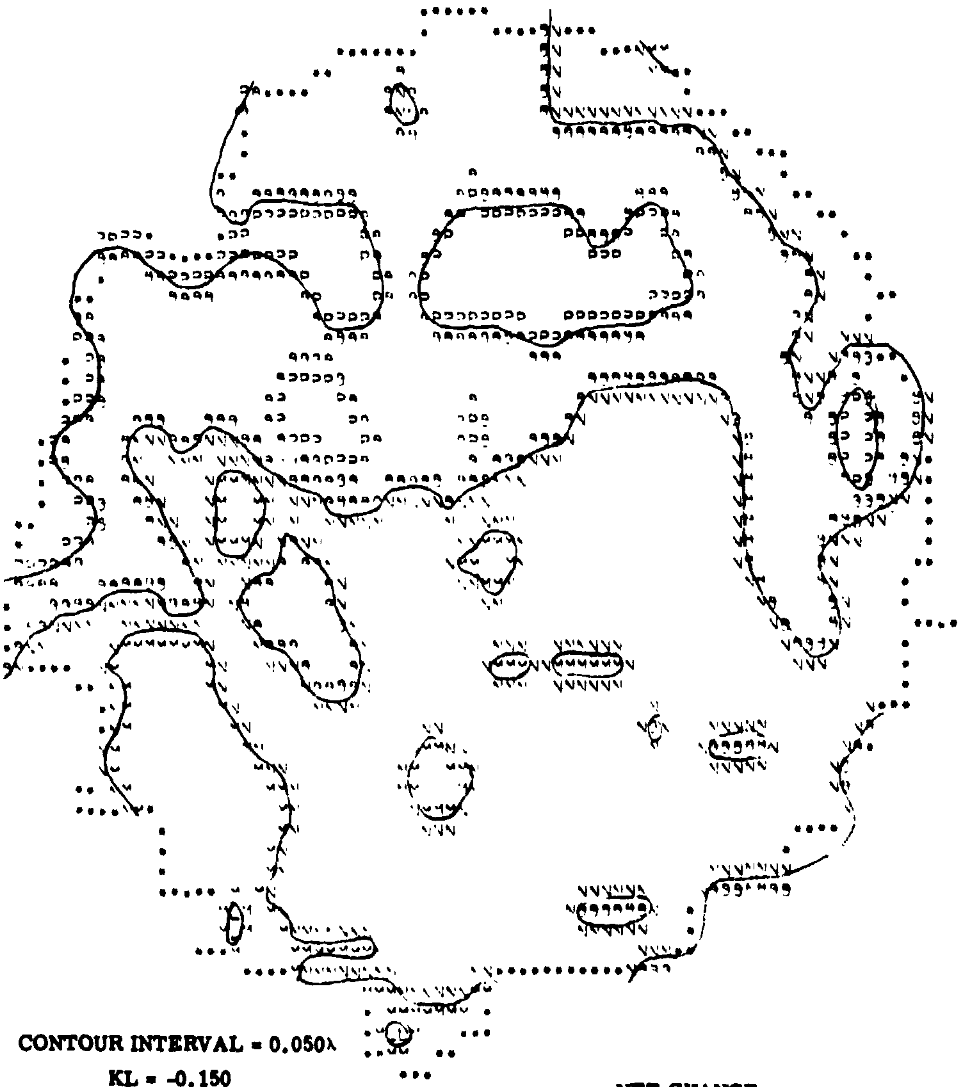


Figure 11. Difference Between 20°C and 0°C



CONTOUR INTERVAL = 0.050λ

KL = -0.150
LM = -0.100
MN = -0.050
NO = ZERO
OP = 0.050
PQ = 0.100
QR = 0.150

NET CHANGE

p.p. = 0.2195
r.m.s. = 0.382

Figure 12. Difference Between 20°C and -57°C

and -57°C). Cooling and heating rates were approximately 0.5°K/min. The mirror was kept at each end temperature for 1.5 hours. Interferograms were recorded before the first cycle and after the first, fifth, and twentieth cycle.

Figure 13 is a contour map showing the net figure change after twenty cycles, and was made by subtracting the last interferogram from the initial one. No change in figure is observed to have occurred after twenty cycles from 293.15°K to 216.15°K (20°C to -57°C).

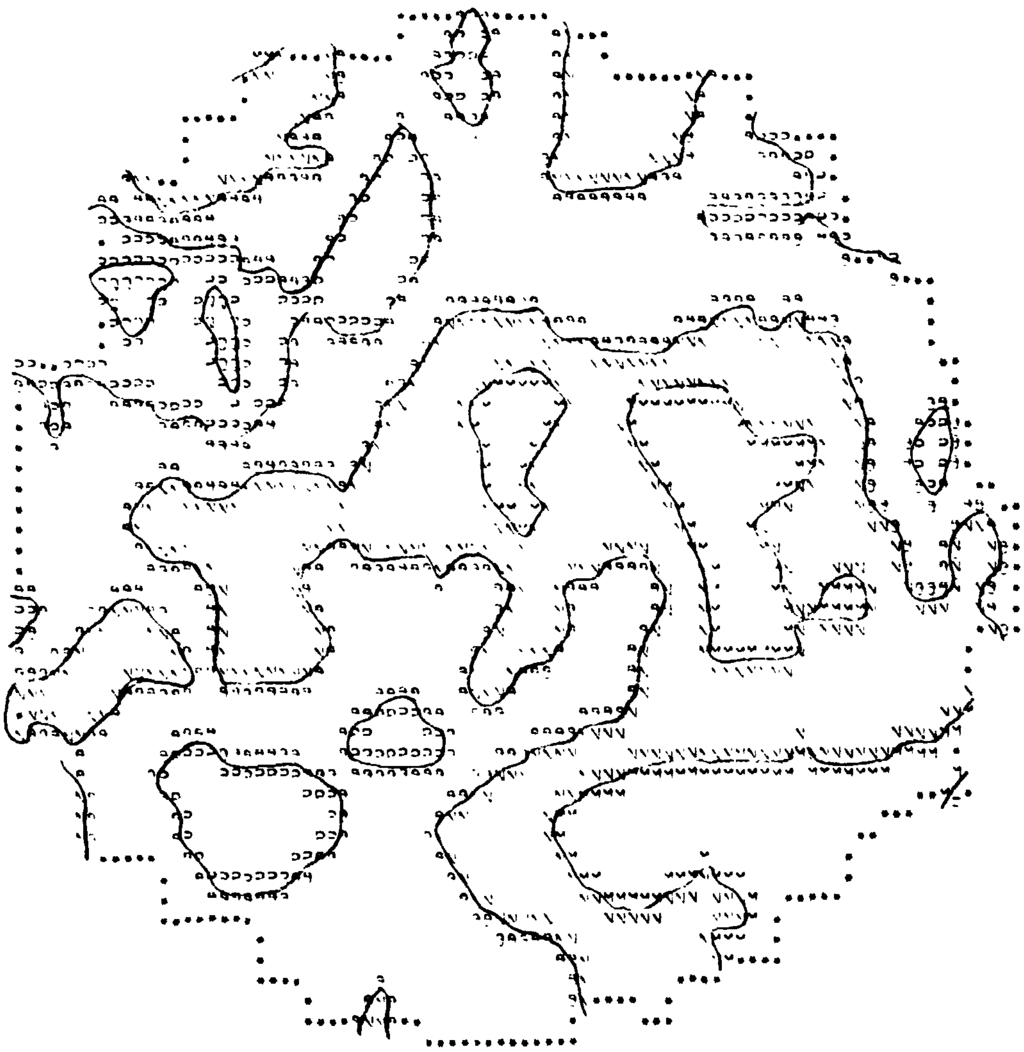
3.5 DEFLECTION MEASUREMENTS

3.5.1 Mounting Configuration

The self-weight deflection of the CerVit mirror blank was measured as a function of support position. For these tests the mirror was mounted (with its optical axis vertical) on three supports spaced 2.1r (120 degrees) apart. Measurements were taken with the supports located at 0.66, 0.25, and 0.91 of the radius of the mirror's aperture. The specific configuration of these supports is shown in Figure 14. Each of three stainless steel upper pads (B) shown in the figure was 3.81cm (1.5 inches) in diameter by 1.27cm (0.5 inch) thick. They were ground flat and attached to the back of the mirror (A) with double-sided tape. The bottom pads (D) were free to slide on the mounting plate (E) so that any movement of the mounting plate relative to the mirror could cause no torques or moments to be applied to the mirror. This was accomplished by attaching a 0.0127cm (0.005 inch) thick by 3.81cm (1.5 inch) diameter piece of Teflon to the bottom of the lower pads (D) with double-sided tape. The 0.0953cm (0.375 inch) diameter steel balls (C) rested in shallow conical seats in the upper and lower pads and provided a self-leveling action. This mounting arrangement was used for both the thermal stability and self-weight deflection measurements.

3.5.2 Expected Deflection Characteristics

Based upon previous experimental and theoretical analysis of these mirrors, changes in optical figure due to self-weight deflection are not



CONTOUR INTERVAL = 0.050λ

KL = -0.150
LM = -0.100
MN = -0.050
NO = ZERO
OP = 0.050
PQ = 0.100
QR = 0.150

NET CHANGE

p.p. = 0.2584λ
r.m.s. = 0.0411λ

Figure 13. Difference Between 1st and 20th Thermal Cycle

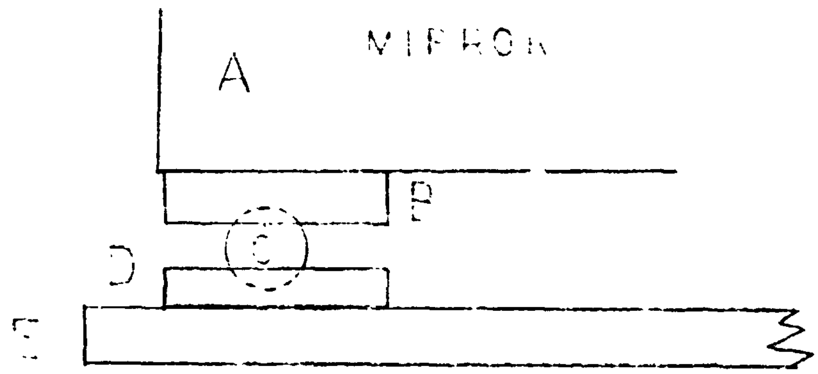


Figure 14. Mounting Pad Design

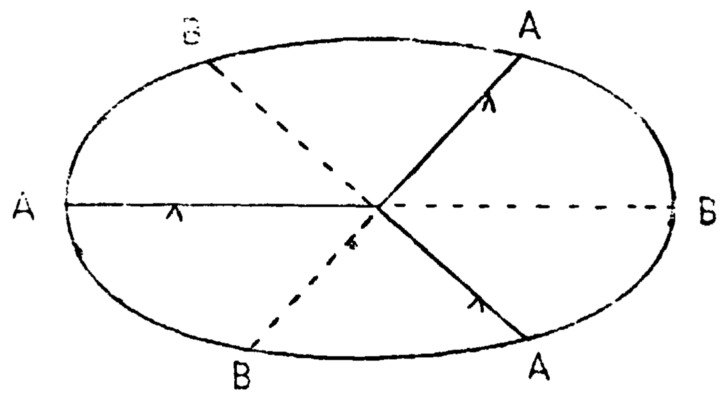


Figure 15. Deflection Geometry

rotationally symmetric about the mirror's optical axis, but instead are periodic in angle as shown in Figure 15. The change in figure along the three radii corresponding to the support radii (a) are equal, but different from the figure change occurring along the other three radii (b).

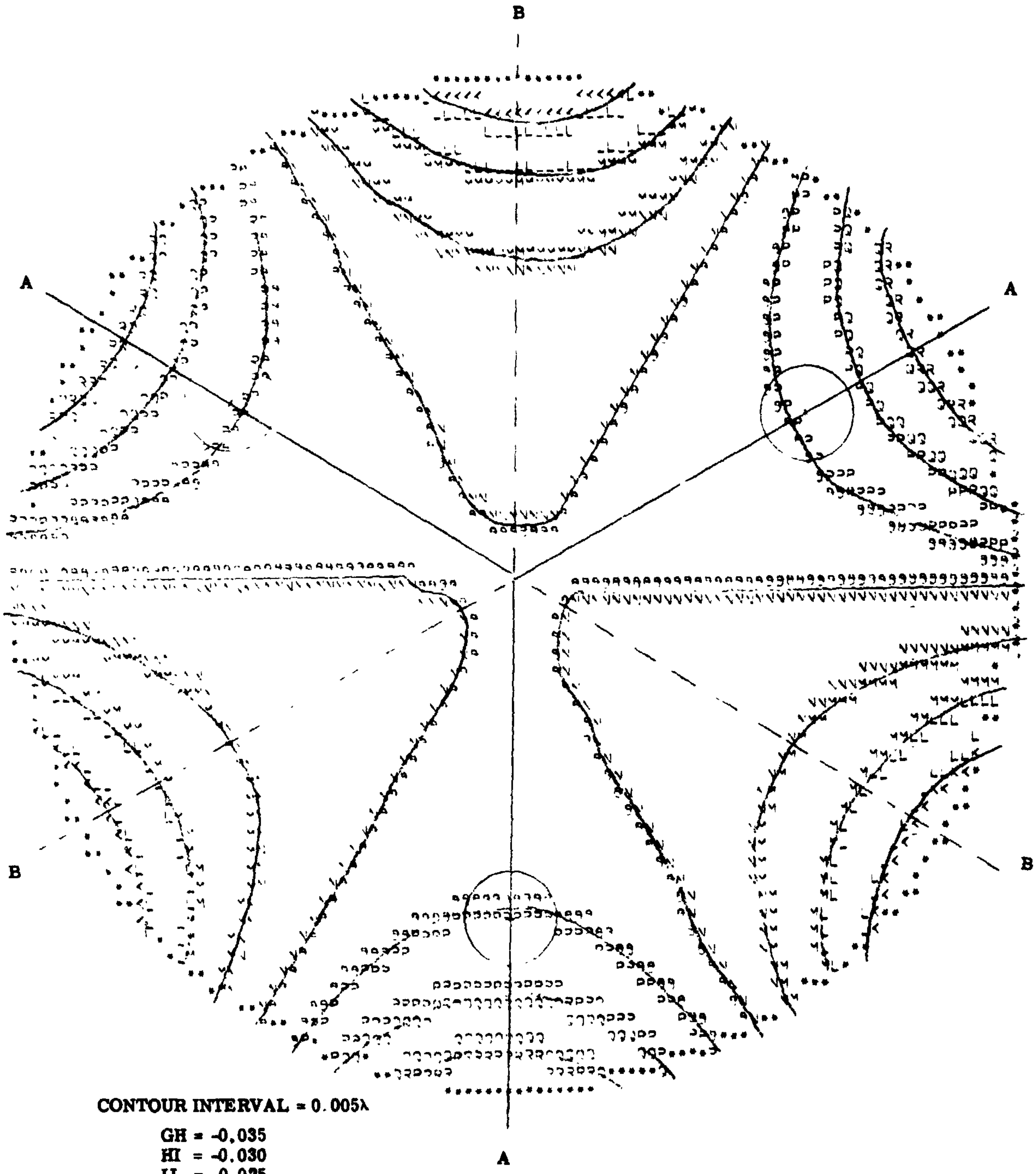
No further prediction concerning the mirror's expected deflection characteristics can be validly made until a detailed mechanical analysis as has first been obtained. It is reasonable to expect that the bending of a mirror of such low aspect ratio does not follow classical "plate theory". Instead the experimental results obtained shall be given in the next section.

3.5.3 Experimental Results

Visual inspection of the interferograms showed no apparent change in figure among the three support positions. Standard computer reduction also showed no clear evidence of a periodic change even when the 0.91R and 0.25R interferograms were subtracted. The mirror behaved as a stiff, or low-aspect, ratio structure.

In an attempt to estimate these deflections more closely, a special computer analysis was run which plotted those coefficients of the aberration power series with threefold symmetry. Two such functions 1.048r (60 degrees) apart were fitted to the data obtained from the interferograms. These are designated x and y third order clover functions. Fifth and seventh order terms were neglected for the purpose of this experiment. The results were plotted and are shown in Figures 16 through 18. While this test analysis technique is still experimental, the maps do indicate relative deflections along the (a) and (b) directions for each mounting configuration that satisfy all of the requirements tabulated in Section 4.2.

(1) The map for the 0.66R mounting position (Figure 16) shows the least overall distortion of the three mount conditions. The deflections along (a) and (b) are of opposite sense and are, respectively, -0.015λ and $+0.015\lambda$ with respect to the center.



CONTOUR INTERVAL = 0.005λ

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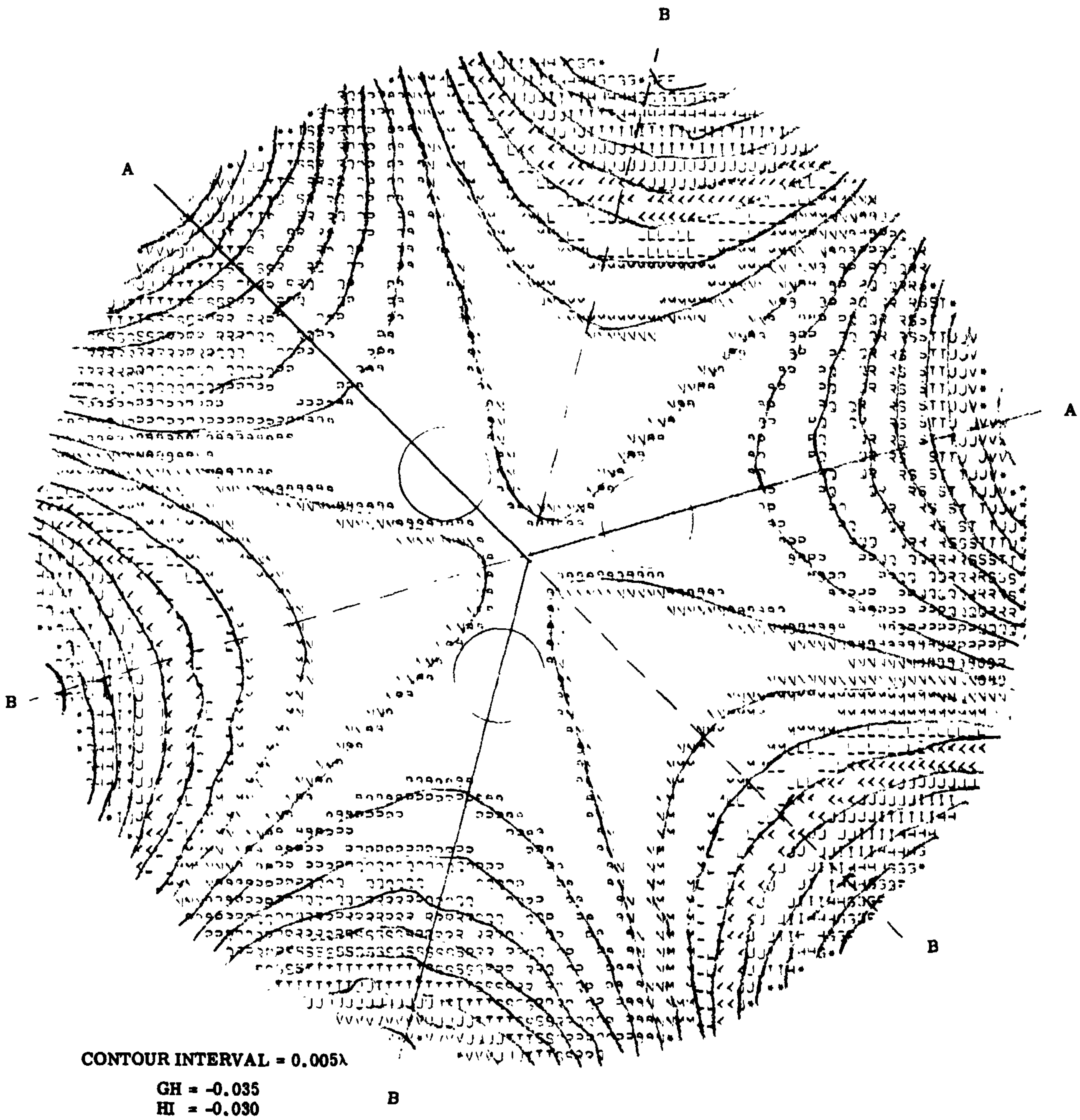
HI = -0.030
IJ = -0.025
JK = -0.020
KL = -0.015
LM = -0.010
MN = -0.005
NO = Zero
OP = 0.005
PQ = 0.010
QR = 0.015
RS = 0.020
ST = 0.025
TU = 0.030
UV = 0.035

NET CHANGE

p.p. = 0.0414λ
r.m.s. = 0.0075λ

Figure 16. 0.66R Support Radius

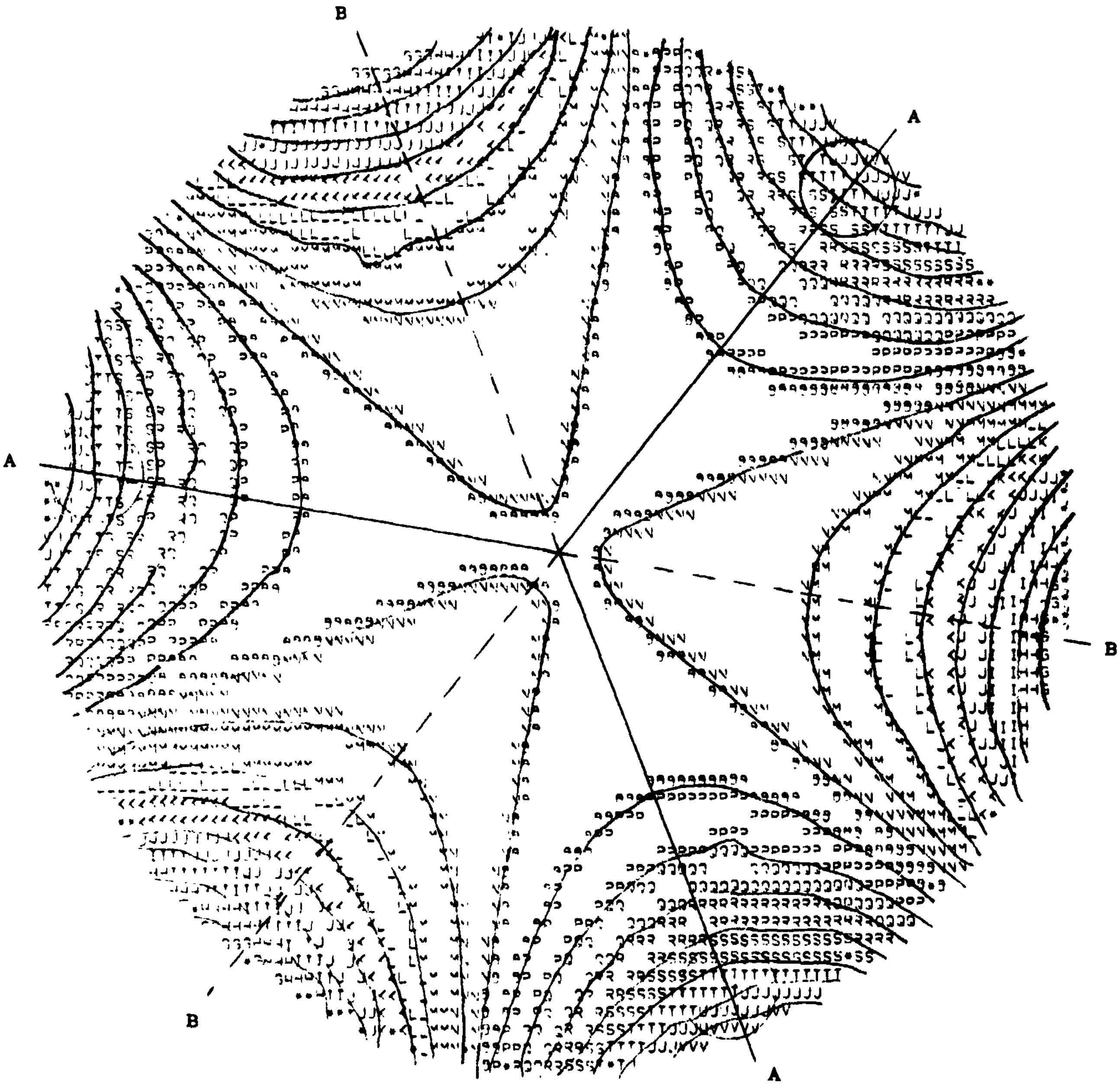


CONTOUR INTERVAL = 0.005λ

GH = -0.035
HI = -0.030
IJ = -0.025
JK = -0.020
KL = -0.015
LM = -0.010
MN = -0.005
NO = Zero
OP = 0.005
PQ = 0.010
QR = 0.015
RS = 0.020
ST = 0.025
TU = 0.030
UV = 0.035

NET CHANGE
p.p. = 0.0866λ
r.m.s. = 0.0158λ

Figure 17. 0.25R Support Radius



CONTOUR INTERVAL = 0.005λ

GH = -0.035
HI = -0.030
IJ = -0.025
JK = -0.020
KL = -0.015
LM = -0.010
MN = -0.005
NO = Zero
OP = 0.005
PQ = 0.010
QR = 0.015
RS = 0.020
ST = 0.025
TU = 0.030
UV = 0.035

NET CHANGE

p.p. = 0.0814λ
r.m.s. = 0.0146λ

Figure 18. 0.91 Support Radius

(2) Edge deflections are larger for the 0.25R case and amount to $+0.035\lambda$ and -0.035λ, respectively, along the (a) and (b) direction. (See Figure 17.)

(3) Edge deflections for the 0.91R case amount to $+0.035\lambda$ and -0.035λ along the (a) and (b) radii, as shown in Figure 18.

(4) The deflections observed for the 0.25R and 0.91R mount configuration are comparable. They are approximately 2.33X the deflection observed for the 0.66R mounting arrangement. The RMS figure deviations are 0.008λ, 0.016λ, and 0.015λ for the 0.66, 0.25, and 0.91 mount positions.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The test results of Phase II reinforce those obtained in Phase I and indicate that the CerVit blank has good uniformity of expansion coefficient, excellent thermal figure stability, and low internal stress. Remarkably little change was observed after the extensive lightweighting activity, so that it was not found necessary to re-figure the mirror after lightweighting. In its present condition the mirror is very rigid. Any changes in self-weight deflection due to mounting configuration are extremely small. On the basis of these test results, premium grade CerVit, type C-101, shows excellent thermal mechanical and optical properties and is well suited for use in lightweight large aperture mirrors in critical applications.

Since the test mirror in its present lightweighted state is still very rigid, further lightweighting is quite feasible and is recommended. In particular, the cavity access-hole diameter can be enlarged, and the backplate thickness of 3.8 cm (1.50 inches) can be reduced. Specifically, it is advisable that:

(a) An analysis should be performed to determine the proper extent of change in backplate thickness, frontplate thickness, and access-hole diameter.

(b) These changes are to be made in increments of 0.635cm (0.25 inch) for the hole diameter and 0.317cm (0.125) inch for the backplate.

(c) Surface figure change be interferometrically monitored as a function of material removal.

Execution of these studies would ensure optimization of the lightweighting and make possible an extremely efficient design for large aperture, lightweight optical mirrors suitable for very critical applications.

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APPENDIX A

Owens-Illinois Lightweighting Test Report

Owens-Illinois, Inc.

CORPORATE NEW PRODUCT DEVELOPMENT

Project Report

QUALITY ASSURANCE
INSPECTION DATA

LIGHTWEIGHT MIRROR BLANK
17¼" Ø x 12"

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
ORDER NO. NAS5-17669
P/N GF-1297267
REVISION C (1-21-72)

TABLE OF CONTENTS

LIGHTWEIGHT MIRROR BLANK
17¼" Ø x 12"
GODDARD SPACE FLIGHT CENTER
ORDER NO. NAS5-17669
P/N GF-1297267
REVISION C (1-21-72)

OWENS-ILLINOIS

DEVELOPMENT CENTER

1020 N. WESTWOOD AVE. TOLEDO, OHIO 43607

CORPORATE NEW PRODUCT DEVELOPMENT

May 31, 1972

National Aeronautics and Space
Administration
Goddard Space Flight Center
Greenbelt, Maryland, 20771

Reference: 17¼" Ø x 12" Lightweight Cer-Vit® Optical Mirror Blank
P/N GF-1297267
Revision C (1-21-72)

Gentlemen:

Owens-Illinois, Inc. certifies that the material in this shipment meets the requirements of the reference purchase order and drawing requirements, and that inspection tests and reports are on file for your review in the Quality Assurance office of Owens-Illinois, Inc., Development Center.

Very truly yours,

OWENS-ILLINOIS, INC.

Robert J. Kamenca 6-1-72

Robert J. Kamenca
Quality Engineering

RJK:jp

R. B. Lackie 6-1-72

Concurred by:
R. B. Lackie
Quality Assurance

K. L. Moan

K. L. Moan
Manager of Operations

GODDARD SPACE FLIGHT CENTER
17¼" Ø x 12" Lightweight Mirror Blank
P/N GF 1297267
Revision C (1-21-72)

Drawing or Contract Requirement	Actual Reading	Type of Insp.	Comments	Insp. Stamp
Outside Diameter 17.250	17.262	Mech.		FI 6
Thickness at O.D. Edge 12.197	12.197	Mech.		FI 6
Thickness of Frontplate .800	.798			FI 6
Thickness of Backplate 1.55	See Attachment #2			FI 6
Cavity Hole Diameter Typical Seven (7) Places	See Attachment #3			FI 6
Web Thickness .35 ± .010	See Attachment #4			FI 6
Cavity Wall Radius .75 ± .010 TYP		Tool Verification	Reference C Change	FI 6
Chamfer Bottom O.D. 1/16" x 45°	1/16" x 45°	Mech.		FI 6
Weight	119 lbs.	Toledo Scale		FI 6
Hole Chamfers	1/8" x 45°		See IR #1891	FI 6 6-1-72

Page ______ of ______
No. ______
MRB# ______
Date ______

INSPECTION REPORT

Inspection after return from Goddard surface is curved & polished.

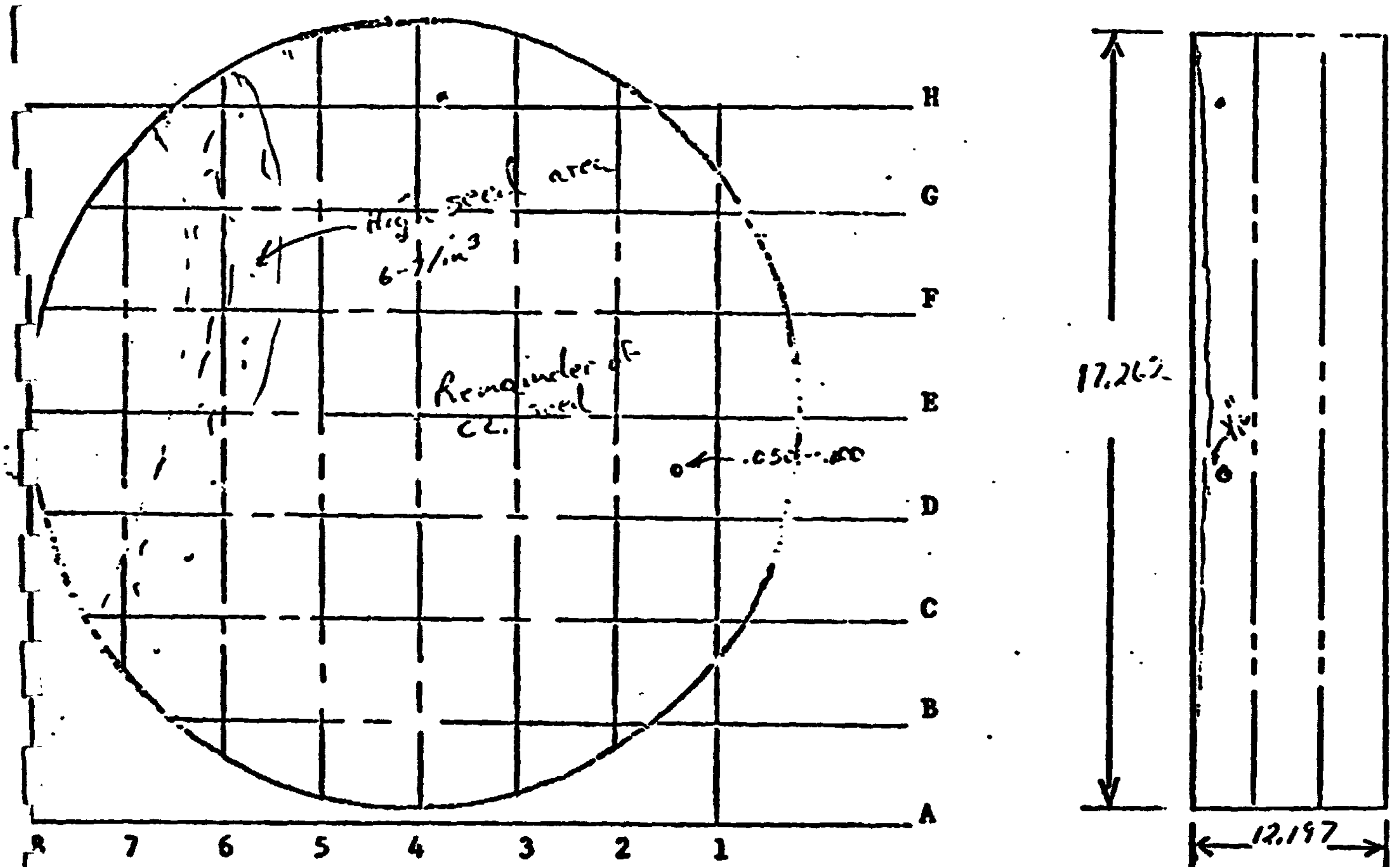
Part Name & Size ______ Customer Goddard Space Flight Center

Customer P/O# ______ Prod. # 3017.103 Inv. # ______

Comp. C101 Furn. & Melt 04072M5 Cast # 3 Exp. -0.9

Seed C2/ Ave. 2-3 /in^3 Mean & Max Dia. .020 Striae None Observed

Stress 2-4 mμ/cm of diffuse strain



Remarks Sag .415"

Insp. Sign. & Date
J.J.M 12/27/71

Insp. Superv. Sign. & Date

NASA/GSFC
17¼" Ø x 12" Lightweight Mirror Blank
P/N GF 1297267
Revision C (1-21-72)

CAVITY DEPTHS
(From Backplate)

Cavity No.	Drawing Requirement	Actual Reading
82	10.982	10.980
67	10.982	10.979
74	10.982	10.980
89	10.982	10.979
97	10.982	10.984
90	10.982	10.985
75	10.982	10.982

Note: Dimension Before Acid Etch

INSPECTORS STAMP AND DATE FI 7 6-1-72

NASA/GSFC
17¼" Ø x 12" Lightweight Mirror Blank
P/N GF 1297267
Revision C (1-21-72)

BACKPLATE THICKNESS

Cavity No.	Drawing Requirement 1.55 ± .010	Actual Reading
82	1.55 ± .010	1.562
67	"	1.560
74	"	1.560
89	"	1.563
97	"	1.563
90	"	1.562
75	"	1.558

Note: Dimensions Before Acid Etch

INSPECTORS STAMP AND DATE FI 7 8-1-72

NASA/GSFC
17¼" Ø x 12" Lightweight Mirror Blank
P/N GF 1297267
Revision C (1-21-72)

CAVITY HOLE DIAMETERS

Cavity No.	Drawing Requirement 2.75 ± .010	Actual Reading
82	2.75 ± .010	2.754
67	"	2.753
74	"	2.753
89	"	2.753
97	"	2.753
90	"	2.753
75	"	2.753

Note: Dimension Before Acid Etch

INSPECTORS STAMP AND DATE FI 7 6-1-72

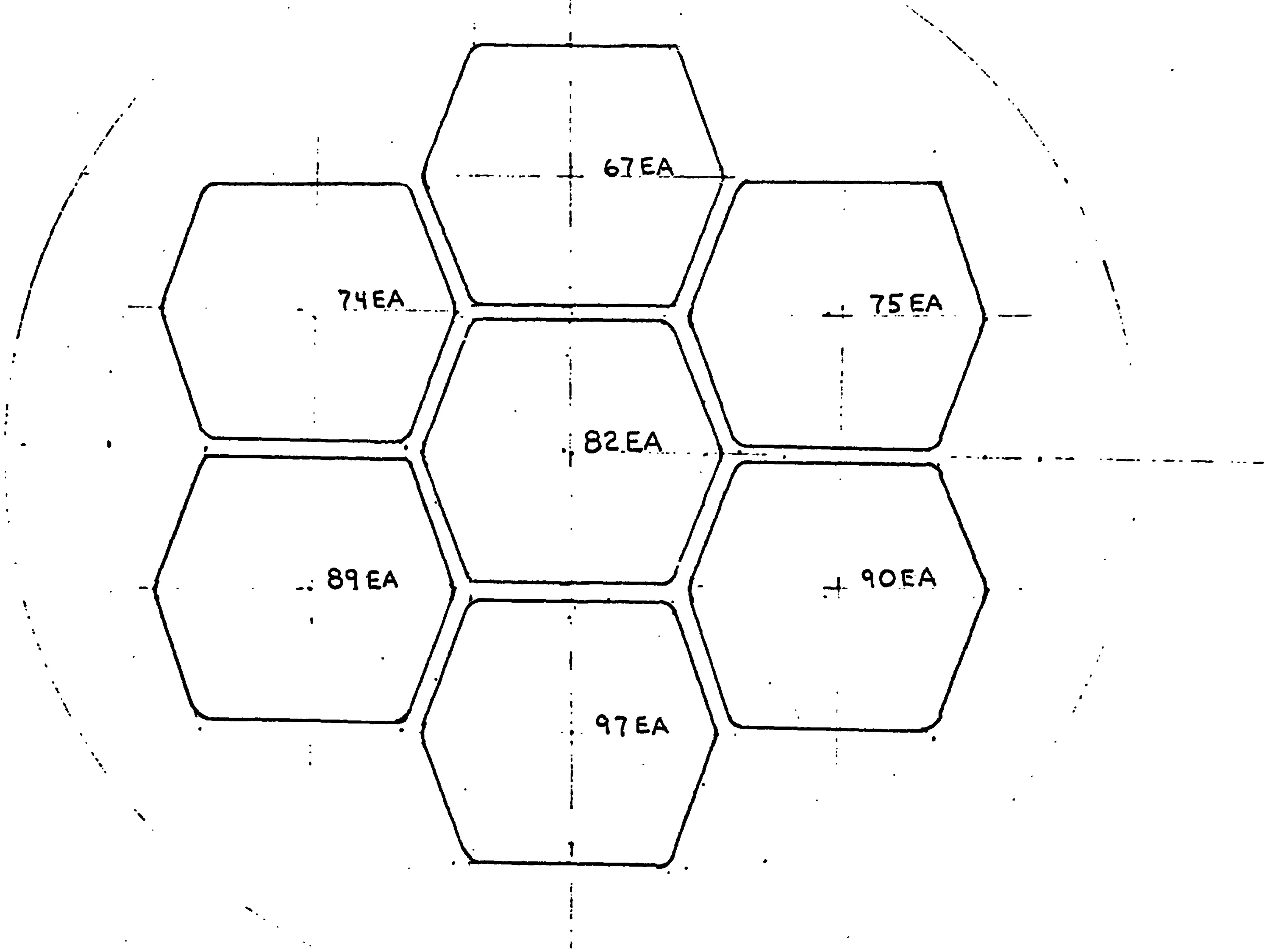
NASA/GSFC
17¼" Ø x 12" Lightweight Mirror Blank
P/N GF 1297267
Revision C (1-21-72)

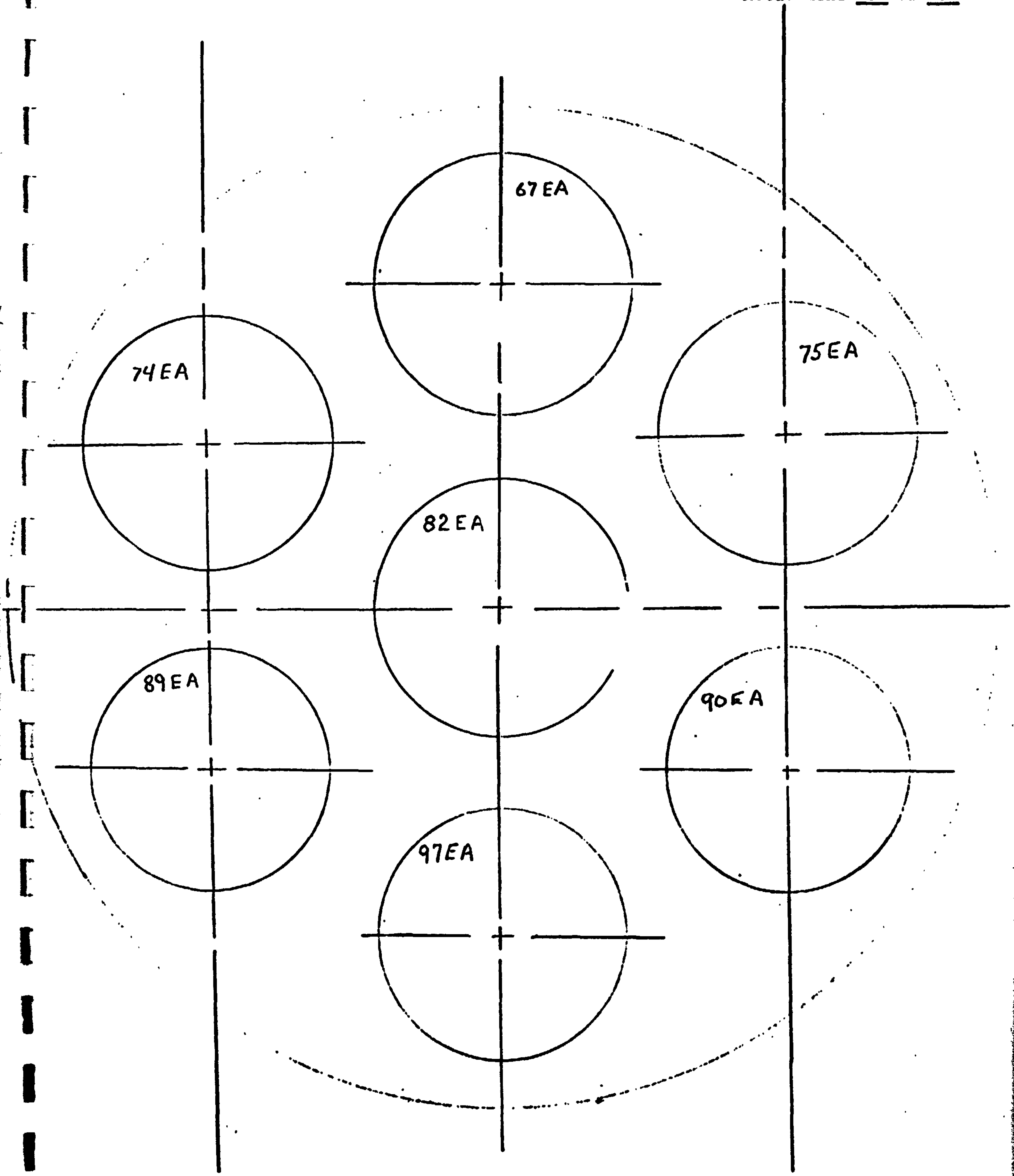
FI 7 6-1-72

WEB THICKNESS SPECIFIED .35 ± .010

Cavity No.	Top	Middle	Bottom	At Radius	Comments
82EA-67EA	.357	.353	.352	.358-.360	
82EA-75EA	.356	.355	.358	.360-.365	
82EA-74EA	.356	.351	.356	.358-.360	
82EA-97EA	.357	.350	.358	.355-.358	
82EA-89EA	.338	.343	.345	.345-.351	See IR #1891
82EA-90EA	.356	.353	.347	.349-.355	
67EA-75EA	.358	.355	.357	.358-.362	
75EA-90EA	.348	.347	.348	.350-.357	
90EA-97EA	.356	.353	.350	.354-.362	
97EA-89EA	.352	.356	.356	.307-.362	.307 Near outer edge of blank IR #1891
89EA-74EA	.350	.351	.355	.355-.360	
74EA-67EA	.355	.356	.348	.350-.360	

Q.A. SKETCH
Attachment 5 of 6




67EA
74EA
75EA
82EA
89EA
90EA
97EA

TEMPERATURE DATA ON COOLANT FLUID

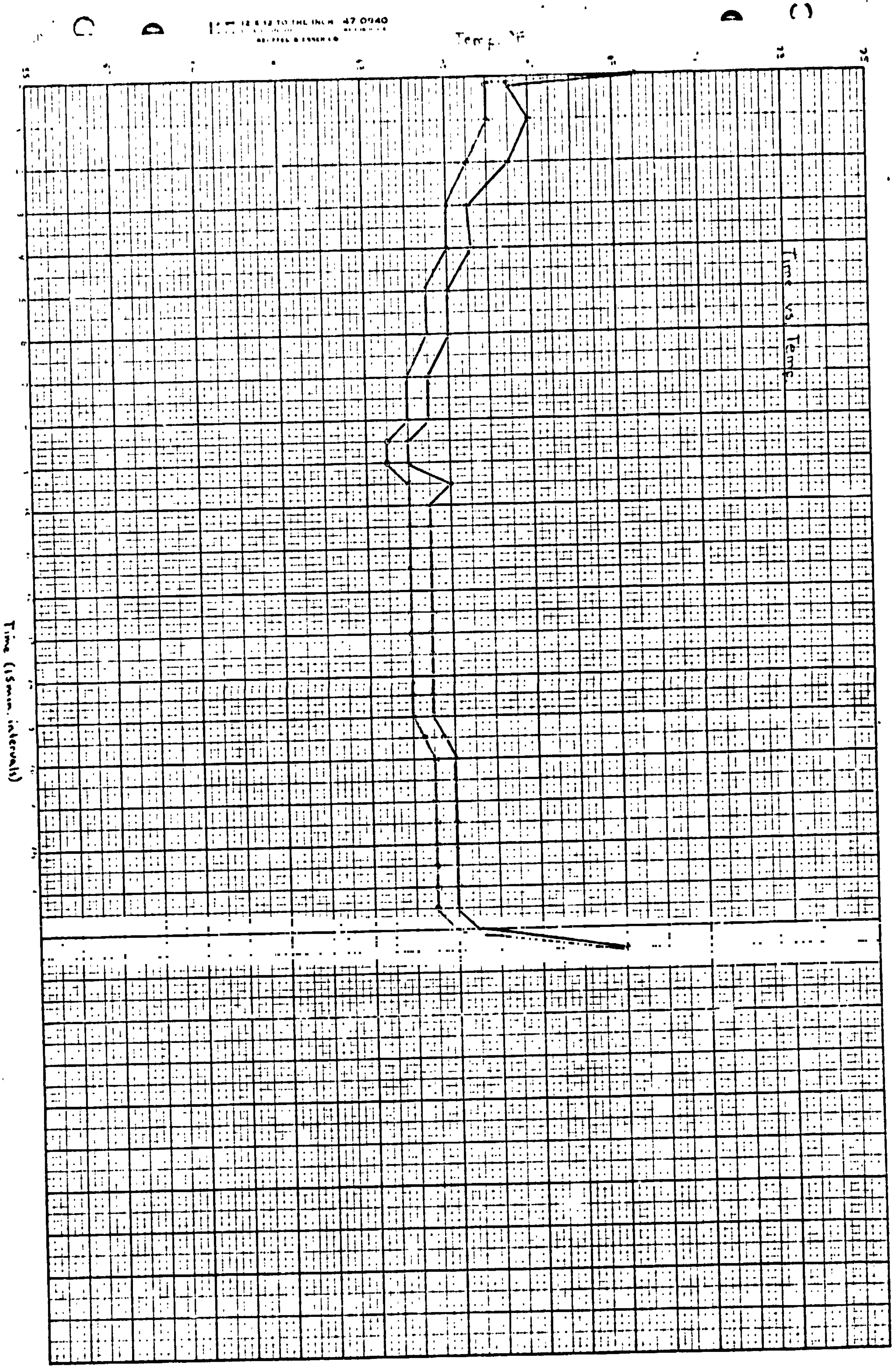
PROCEDURE

1. Attach thermocouple to golf stick adjacent to grinding wheel.
2. Monitor readings at 15 minute intervals.
3. Readings taken on one cavity.
4. Readout device and thermocouple calibrated 11-18-72.
5. Accuracy of device ± .3° F.

Equipment:

Thermocouple - Sheathe type Iron-Constanin

Readout Device - Honeywell Strip Chart Recorder
Model No. 153C1 OPS - 21K1 - 20F1
Serial No. 685095


Temp. °F
Time vs. Temp.
Time (15min. intervals)

Form 143-R2 Page 1

QECV 003

OWENS-ILLINOIS

No. IR - № 1891

CNPD Center

Date 5/31/72

INSPECTION REPORT

Page 1 Of 1

Part Number	Part Name		Supplier/Customer
1297267 D40T2M5-3	17 1/4" ø L.W. Mirror Blank		O. I.
P. O. No.	Total Qnty. Lot	MRB No.	MSRO No./Prod. Lot No.
3017,103	1	1652	

Item	Qty.	Freq.	Description of non-conformance	Prelim. Decision	Disposition/Comments
1		7/7	S/B Back hole plate chamfers		Accept As is.
			$\frac{1}{16} \times 45° \pm \frac{1}{64} \pm 2°$		will not affect
			A/C back hole chamfers 1/8"		CLIES - all
			due to curved surface in		are in process
			flat area accurate & could		dimensions
			not be taken.		R. Luckie
2		2/12	S/B wall thickness .35 ±.010		
			A/C cavity wall 97-89 .307		
			cavity wall 82-89 .338		

Insp. Sgn.	Date	Insp. Supv. Sgn.	Date	Prod. Supv. Sgn.	Date
J. J. Matuszak	5/31/72				

REINSPECTION

Qty. Accept.	Qty. N/C	New I/R No.	Insp. Sgn. & Date	Insp. Stamp
1	0	N/A	B. J. Kerns 5/31/72	61

Q. A. Sgn.	Date	Mfg. Rep. Sgn.	Date
R. Luckie	5-31-72	W. Hiaw 5/31/72	

Proj. Eng. Sgn.	Date	Customer Approval	Date
E. Dunigan	6-1-72		5/31/72

Cause of Discrepancy	Action to prevent recurrence

Purch. Rep. Sgn.	Date ☐ RTV ☐ Scrap	Responsibility	Q/A Sgn.